EGU General Assembly 2020

香港中文大學 The Chinese University of Hong Kong

IEES

Impacts of ENSO and IOD on Snow Depth over the Tibetan Plateau: Roles of Convections over the Western North Pacific and Indian Ocean

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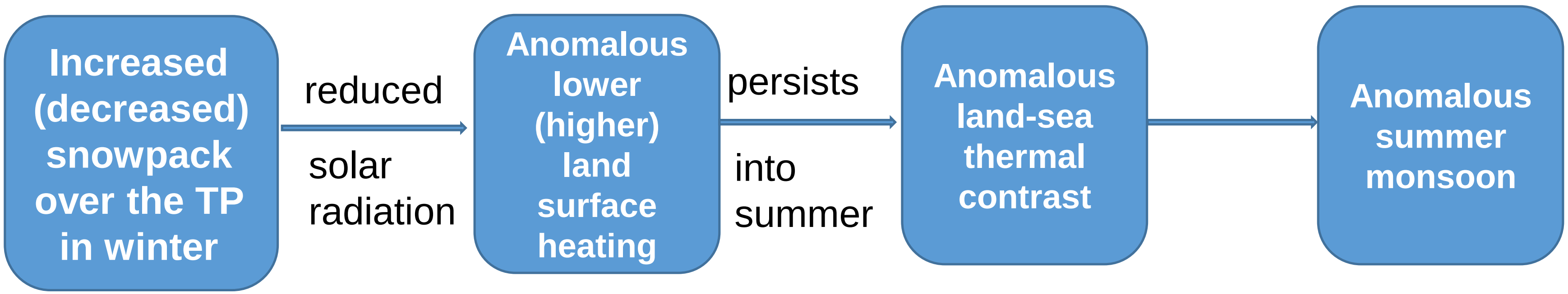
May 7, 2020

CONTENT

Introduction

- ✓ **Snowpack exerts great influence on the thermal status over the Tibetan Plateau (TP) and thus plays important roles in weather and climate over and beyond the Asia (Yeh et al., 1983; Wu and Zhang 1998; Bamzai and Shukla 1999; Zhao and Chen 2001; Xie et al., 2005; Wang et al., 2017).**



- ✓ **Therefore, understanding of the TP snow variation provides insights into the variation and prediction of climate and weather worldwide.**

Introduction

- ✓ **The possible causes responsible for interannual variability of snow over the TP, however, are under debate regarding the independent roles of ENSO and IOD.**

  Shaman and Tziperman (2005) proposed that an El Niño might excite the stationary Rossby waves extending along the North African-Asian jet, resulting in anomalous increase of potential vorticity and snow depth over the TP in winter.

  On the other hand, Yuan et al. (2009, 2012) reported that the interannual variability of the winter TP snow cover is linked to Indian Ocean dipole (IOD) rather than El Niño–Southern Oscillation (ENSO).

- ✓ **Thus, it is necessary to reinvestigate the relationship of snow depth over the TP with ENSO and IOD.**

Scientific Questions

- ✓ **Whether the ENSO and IOD can affect snow depth over the TP?**
- ✓ **If yes, what are the independent roles of ENSO and IOD on snow depth anomalies over the TP?**
- ✓ **How ENSO and IOD affect snow depth over the TP?**

Data and Model

Data

The observed daily data sets: snow depth, snowfall, and 2-m air temperature (T2M) for the period of 1980-2010 in China, compiled by the China Meteorological Administration (CMA) after quality control, are used in this study. Stations with elevation above 1000 meter within the TP are selected, leaving a total 79 stations used in this study.

Other data sets: monthly temperature, winds, and moisture flux from ERA-Interim (Dee et al. 2011), SST from the Hadley Centre Global Sea Ice and Sea Surface Temperature (HadISST) version 1.1 (Rayner et al. 2003), and monthly National Oceanic and Atmospheric Administration (NOAA) Interpolated OLR (Liebmann et al. 1996) are also used in this study.

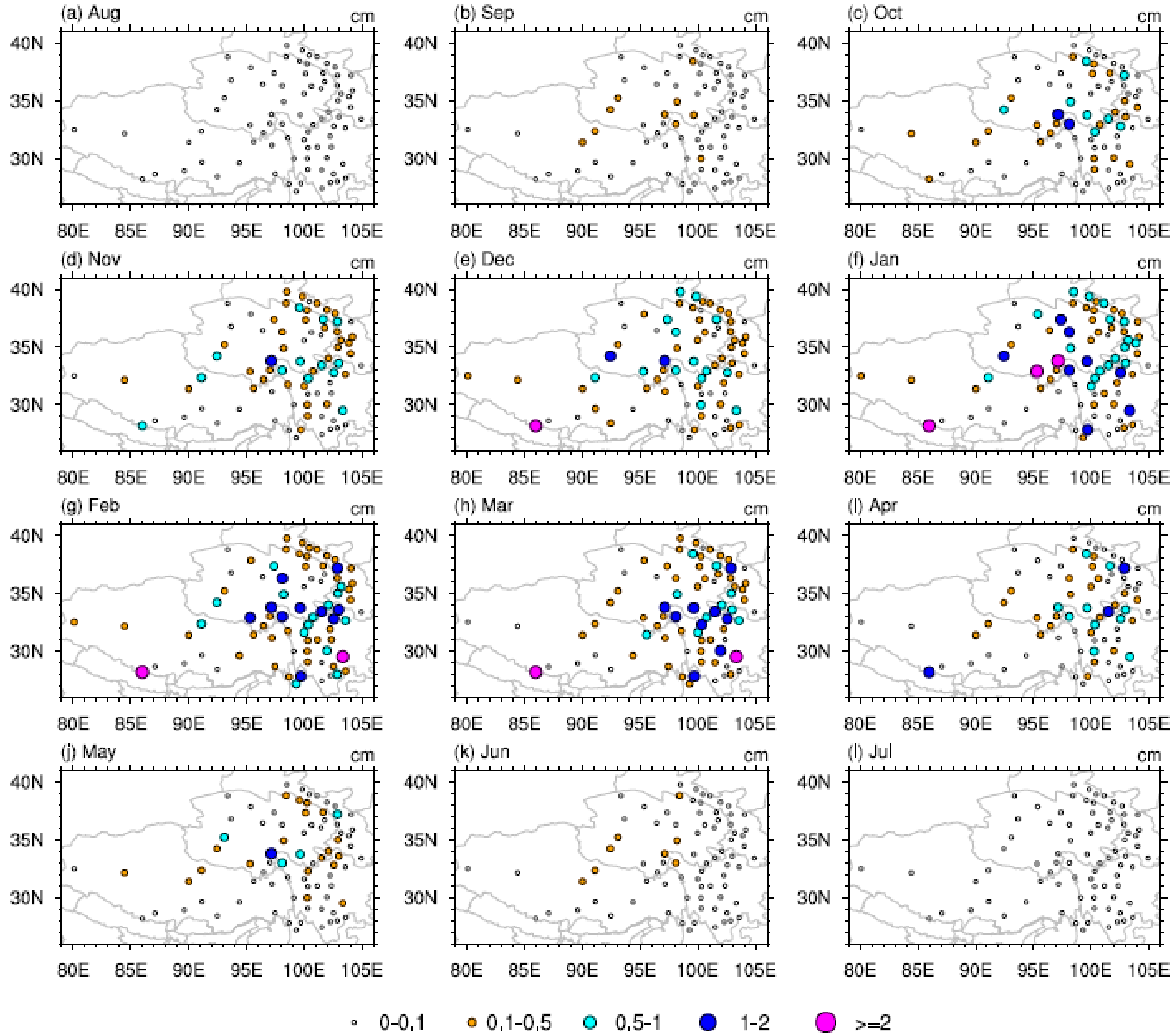
Data and Model

Model

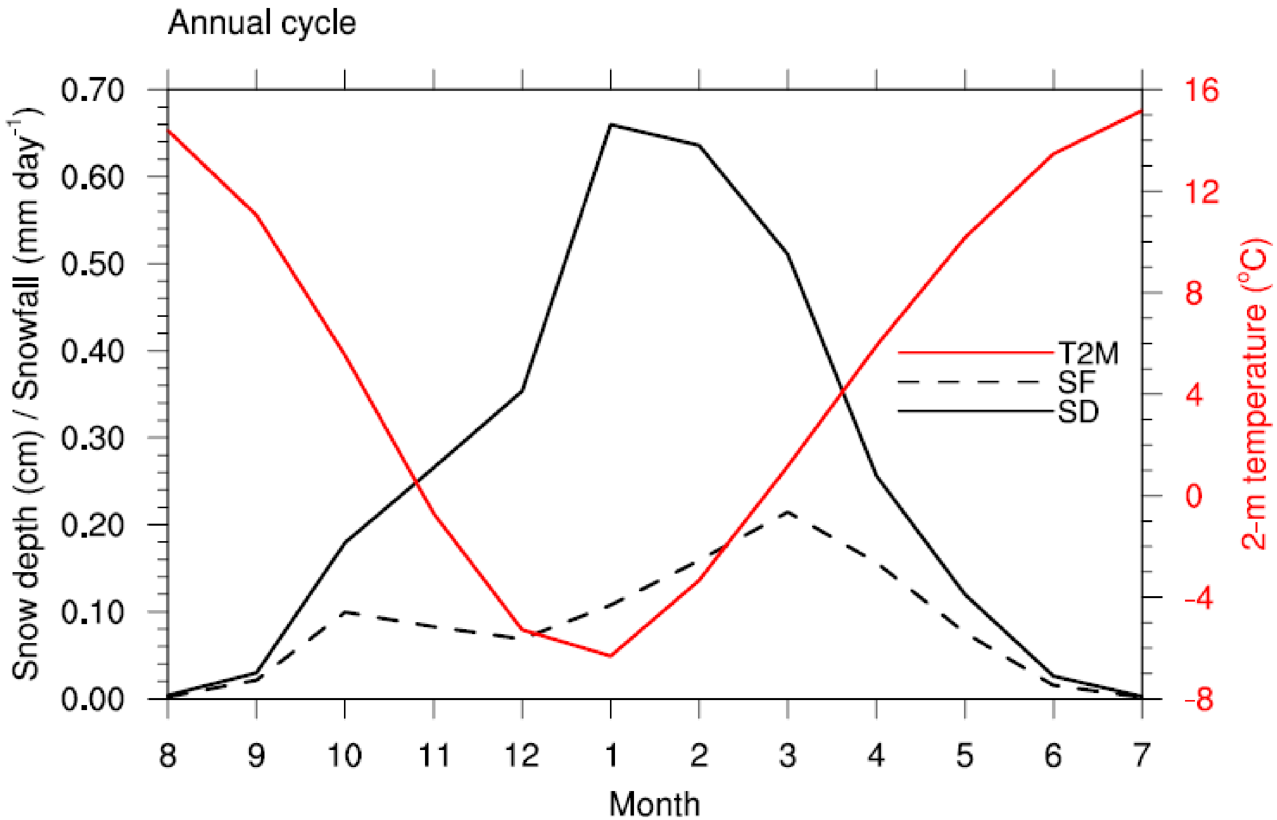
A nonlinear baroclinic model, developed by Ting and Yu (1998), a fully nonlinear, dry, time-dependent baroclinic model with 24 sigma levels in the vertical and spectral R30 horizontal resolution, is employed in this study.

The idealized heating is prescribed as $Q = V(\sigma)A(\lambda, \phi)$. The vertical structure of the heating takes the form $V(\sigma) = e^{(-20\times(\sigma-\sigma_c)^2)}$. It has a maximum when σ equals σ_c and reduces to zero quickly as σ increases or decreases from σ_c. σ_c is chosen to be 0.37 in this study. The $A(\lambda, \phi)$ defines the horizontal structure and magnitude of the heating.

Climatology of snow depth over the TP from August to July

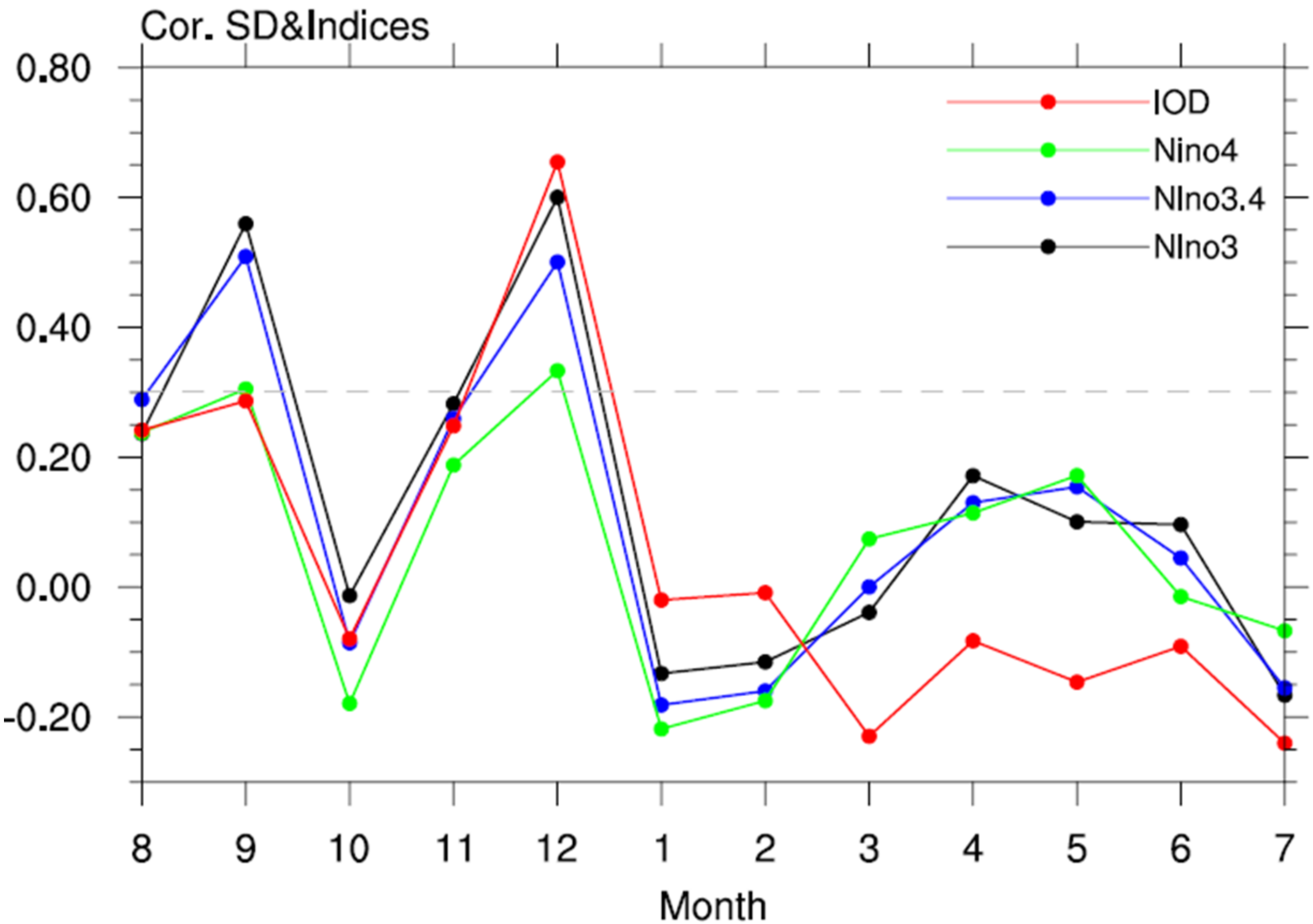


The process of the snow depth is somewhat different between after and before January



Annual cycles of the snow depth (cm; black solid line), snowfall (mm day-1; black dashed line), and 2-m temperature (℃; red solid line) averaged over the TP.

Temporal and Spatial Variabilities of the TP Snow Depth and Its Relationship with ENSO and IOD



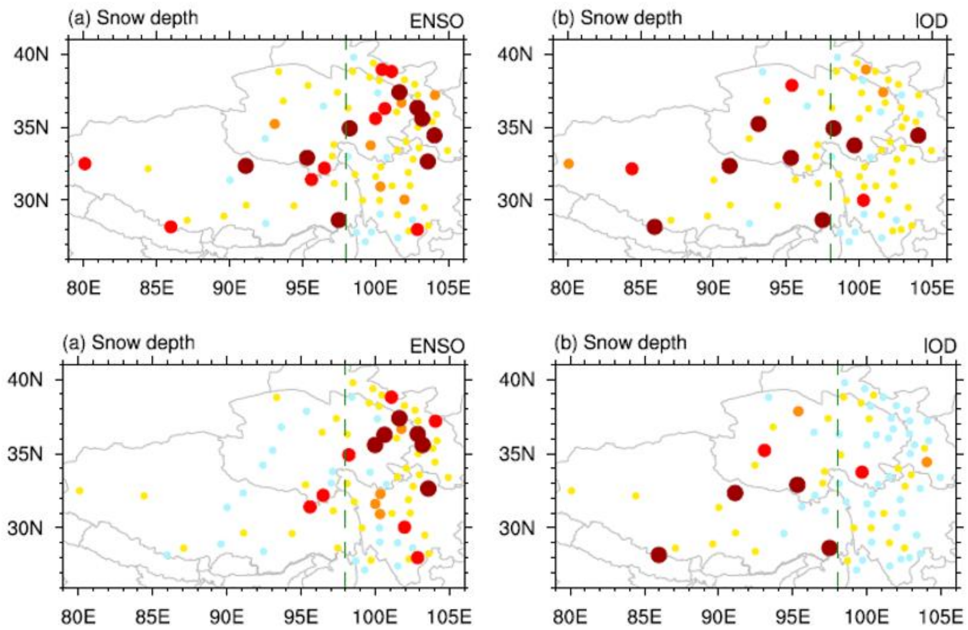
Considerable persistent positive correlation between the TP snow depth index (TPSDI) and ENSO/IOD mainly appears in early winter.

Correlation coefficients of TPSDI with Niño-3 and IOD index during Nov-Dec are 0.52 and 0.61, respectively.

Temporal and Spatial Variabilities of the TP Snow Depth and Its Relationship with ENSO and IOD

Correlation

Partial Correlation

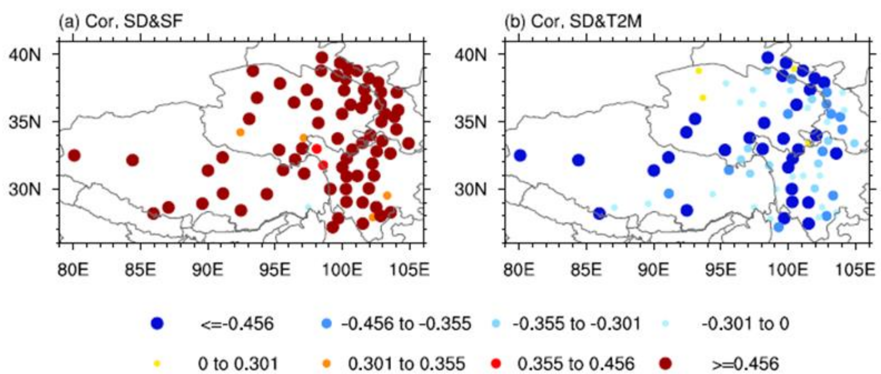


	CWTPSDI	ETPSDI
Niño-3 index	0.345* (-0.193)	0.512*** (0.455**)
IOD index	0.642**** (0.598****)	0.287 (-0.118)

*90%, **95%, ***99%, ****99.9%

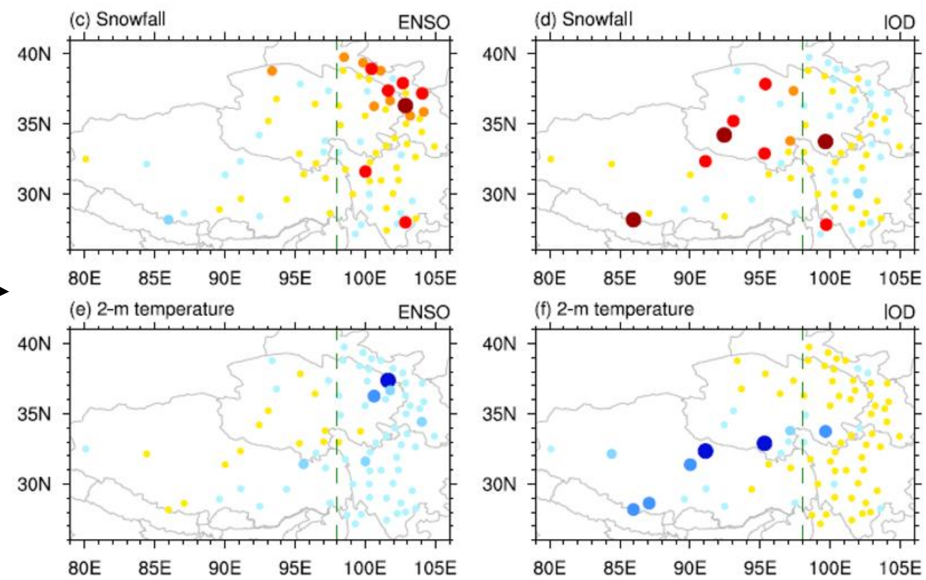
ENSO and IOD have different impacts on snow depth over the eastern TP (ETP) and the central-western TP (CWTP) in early winter!

a. Roles of local snowfall and surface air temperature



Snowfall has a greater influence than surface air temperature on snow depth across the TP in early winter.

Partial Correlation between ENSO/IOD and snowfall/T2M



These features again indicate that the ENSO (IOD) has a closer link to climate anomalies over the ETP (CWTP).

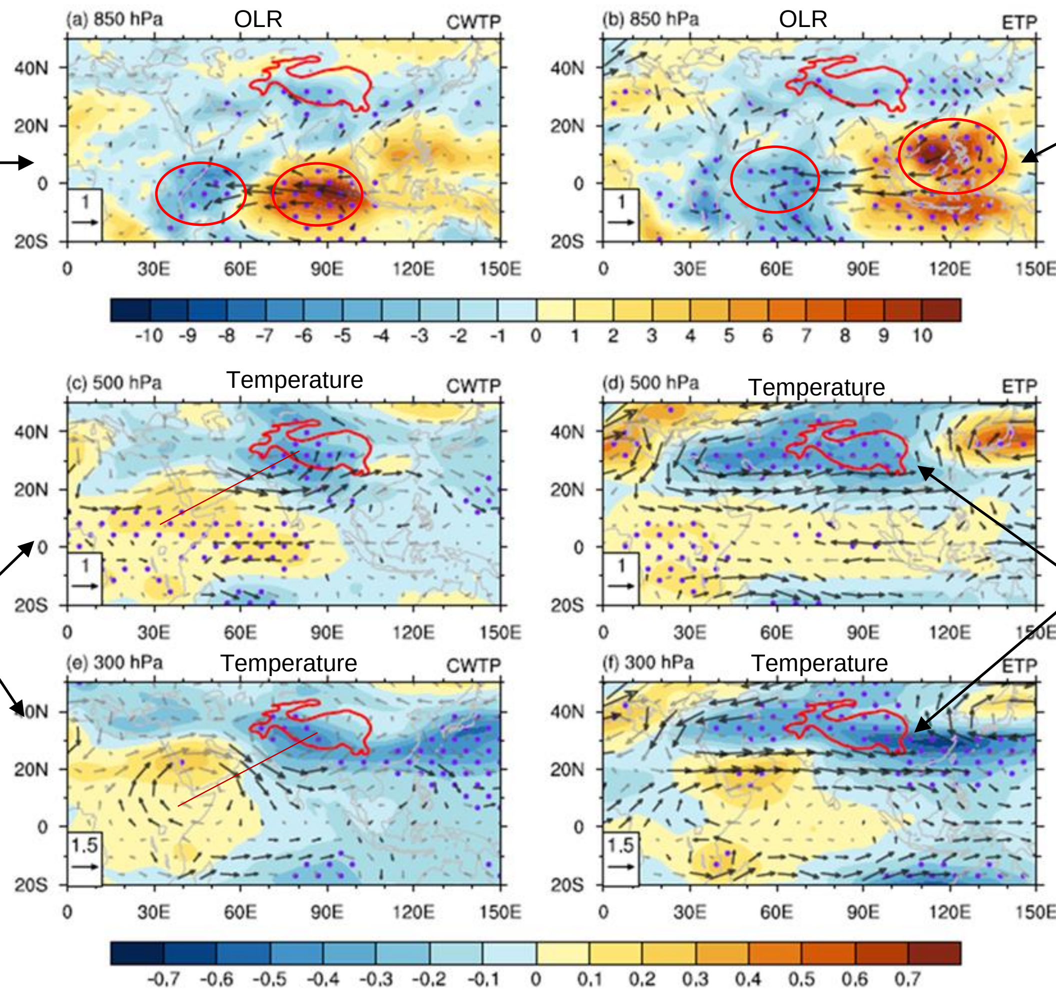
Mechanisms

b. Atmospheric circulation, temperature, and convection anomalies

Negative OLR anomalies over the western IO (WIO) and positive OLR anomalies over the western maritime continent (WMC)

A wave-train propagates northeastward along the South Asian wave guide

Reg of OLR/Temp/winds against CWTPSDI/ETPSDI



Positive OLR anomalies over the WNP and negative anomalies over the WIO

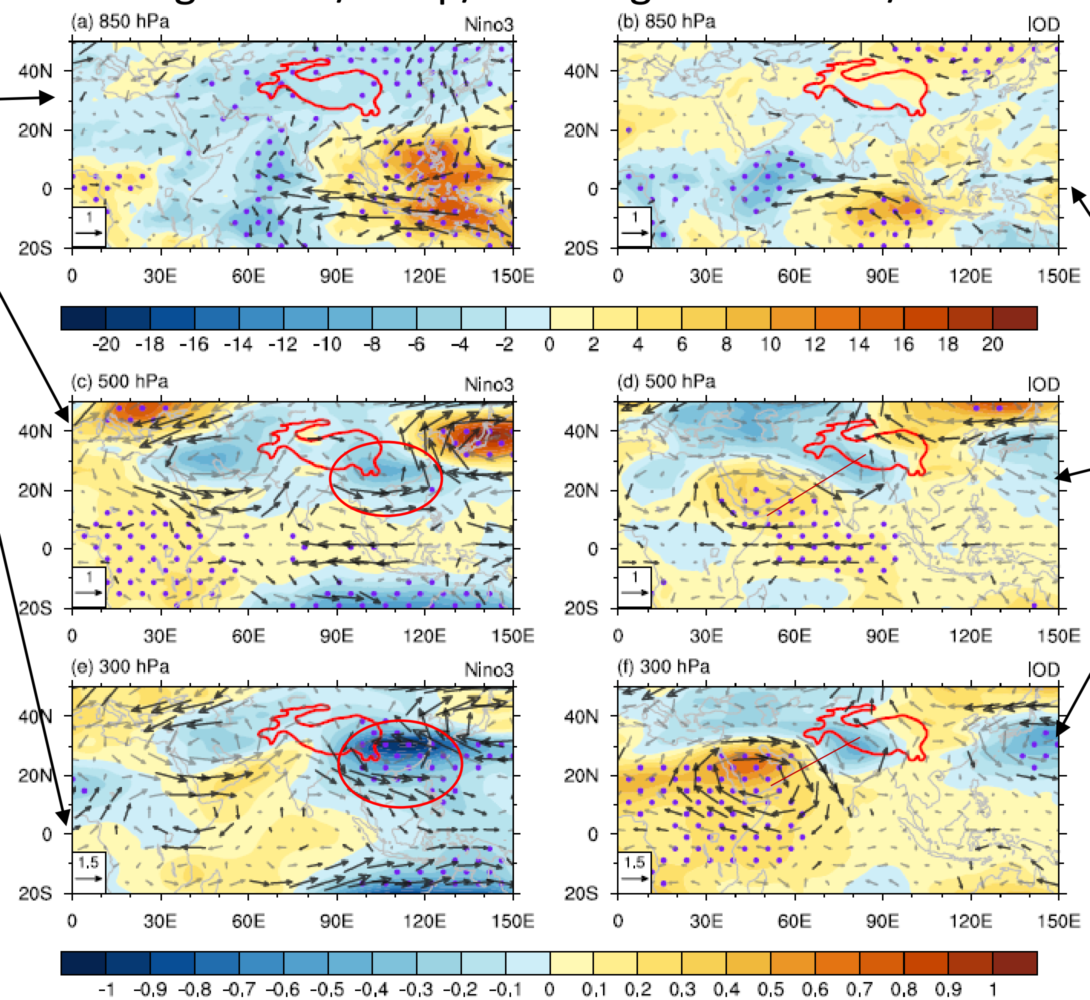
Anomalous cyclonic circulation and cold temperature anomaly are dominant across the TP, southeasterly anomalies from the WNP toward the ETP edge

b. Atmospheric circulation, temperature, and convection anomalies

Par Reg of OLR/Temp/winds against Niño-3/IOD index

Similar with regression patterns for ETP

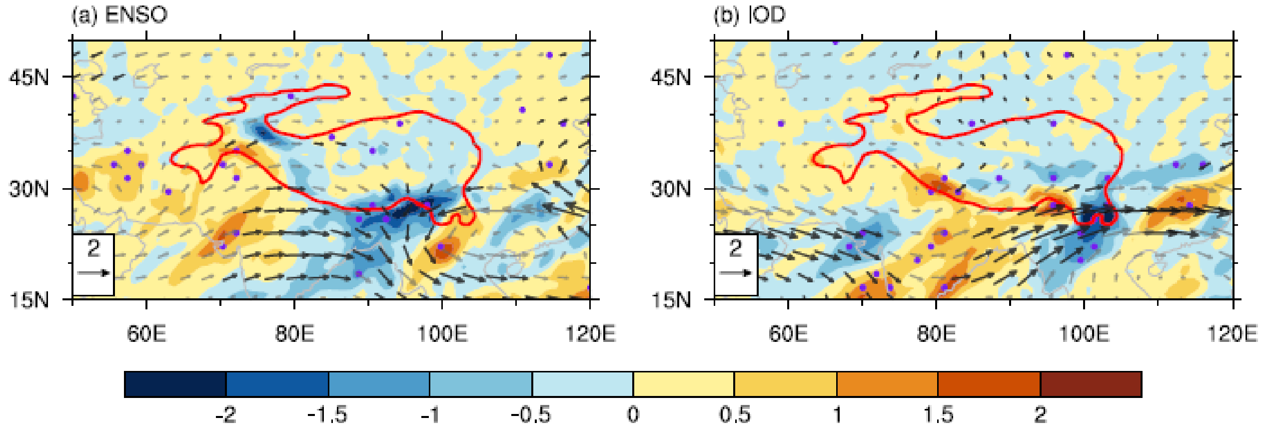
A stronger (weaker) anomalous cyclonic circulation/colder temperature over eastern edge (west) of the TP



Similar with regression patterns for CWTP, except the insignificant cold temperature anomaly over the CWTP.

b. Atmospheric circulation, temperature, and convection anomalies

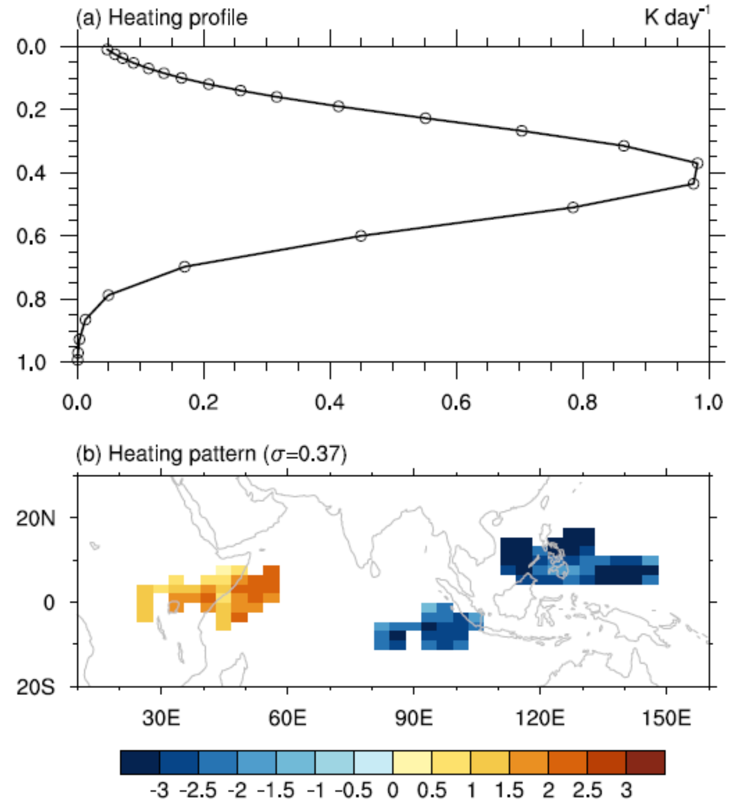
Regressions of vertically integrated moisture flux and its divergence against (a) the Niño-3 and (b) the IOD snowfall indices



- The anomalous circulations, moisture transport, and temperature associated with ENSO are favorable for occurrence of snowfall and deepening of snow depth over the ETP region, but not for the CWTP.
- The wave-train associated with IOD induces anomalous cyclonic circulation over the northern India-CWTP, which favors moisture transport from the northern IO toward the CWTP, thus benefiting snowfall over the region.

c. Role of tropical convections.

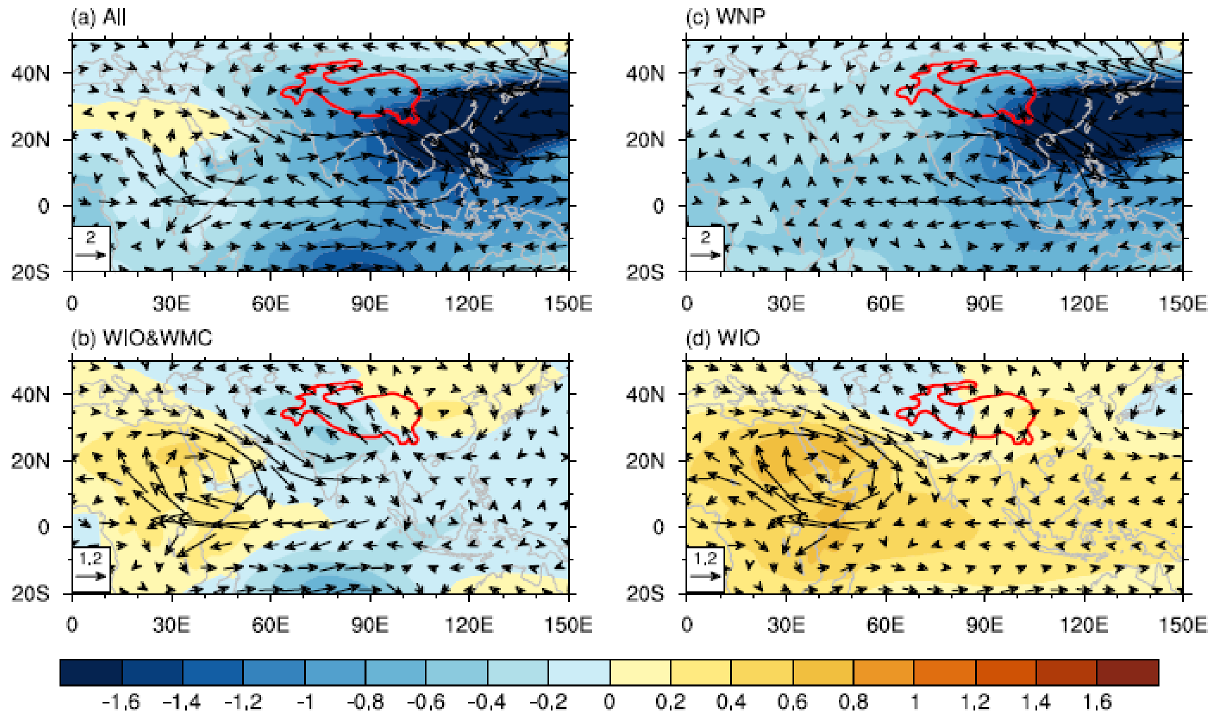
Several experiments are conducted: Heating is limited to (1) the three regions of WIO , WMC, and WNP; (2) the two regions of WIO and WMC; (3) the region of WNP; (4) the region of WIO; (5) the region of WMC where regression coefficient exceeding 90% confidence level.



(a) Vertical profile of specific heat source (K/day) around the horizontal maximum heating center, (b) spatial pattern of specific heat sources (shading; k/day) at the level of sigma equals 0.37.

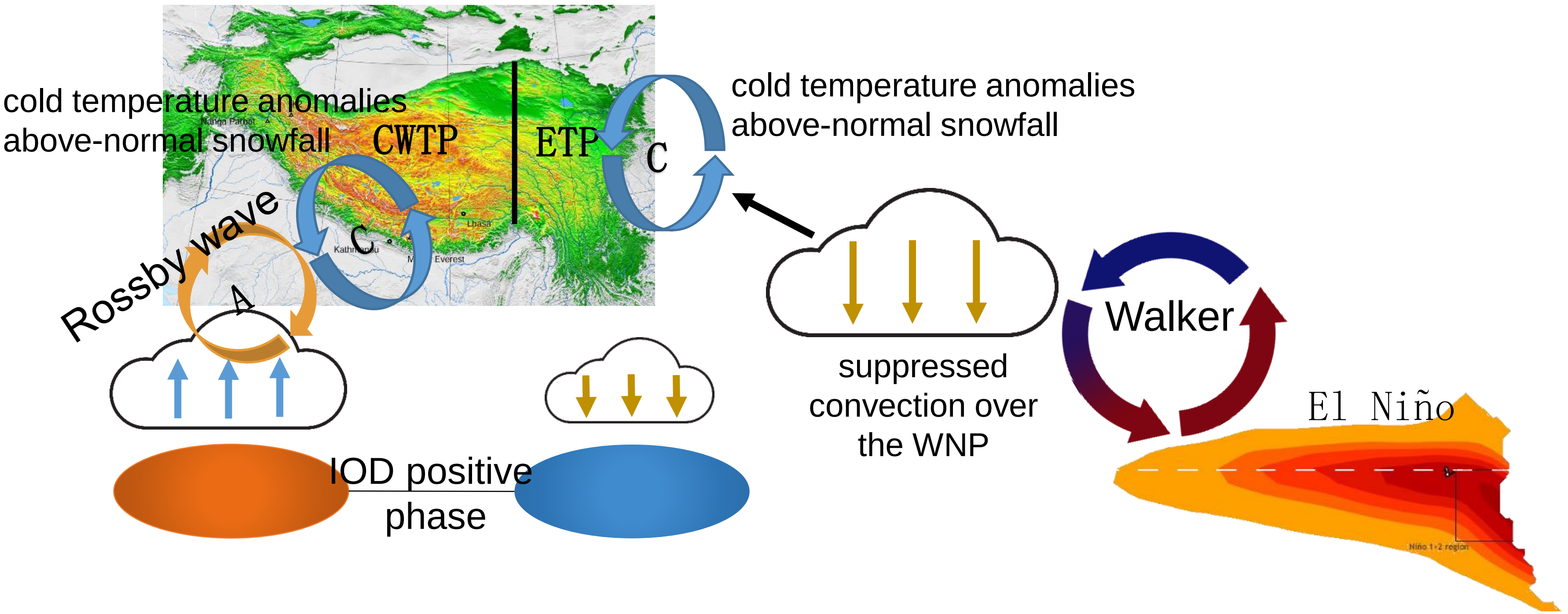
c. Role of tropical convections.

Via exciting regional and remote atmospheric circulations and temperature anomalies, convection over the WNP (WIO) works as a medium by which ENSO (IOD) affects the ETP (CWTP) snow depth.



The responses of winds and air temperature at 300-hPa to heating over the (a) WNP, WMC, and WIO, (b) WMC and WIO, (c) WNP, and (d) WIO.

Summary



- **ENSO mostly affects snow depth (SD) over the ETP during early winter, while IOD affects SD over the CWTP.**
- **Positive phase of ENSO favors deepening of snow depth over the ETP by suppressing convection over the WNP.**
- **Convection anomalies over the WIO associated with IOD could generate a barotropic Rossby wave that propagates northeastward along the South Asian wave guide, providing a favorable condition for occurrence of snowfall and deepening of snow depth over the CWTP.**

THANKS !

Jiang, X., T. Zhang*, C.-Y. Tam, J. Chen, N.-C. Lau, S. Yang, and Z. Wang, 2019: Impacts of ENSO and IOD on snow depth over the Tibetan Plateau: Roles of convections over the western North Pacific and Indian Ocean. *J. Geophys. Res.,* 124, doi: 10.1029/2019JD031384.